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(12) # EUROPEAN PATENT APPLICATION

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(71) Applicant: British Gas Corporation
59 Bryanston Street
London, W1A 2AZ(GB)

(72) Inventor: Hayward, Ian
6 Dunlin Drive
South Beach Estate Blyth Northumberland(GB)

(74) Representative: Wallace, Walter et al,
British Gas Corporation Patents Department 326 High Holborn
London, W1CV 7PT(GB)

(54) **Measurement of velocity and/or distance.**

(57) A non-contact system suitable for measuring velocity/distance of, an object travelling inside a ferromagnetic pipeline utilises magnetic dipoles written into the pipe surface by a transmission coil. These dipoles can be detected by a magnetic detector situated a fixed distance from the transmission point. If the time taken for a dipole to travel from the transmitter to the detector is recorded then this time will be proportional to the velocity of the system.

The system therefore performs a dual role,

(a) as a velocity measurement device, and

(b) as a distance marker.

Once the system detects a dipole it requests a further imprint, hence, a constant spacing is maintained between dipoles equal to the spacing between transmitter and detector.

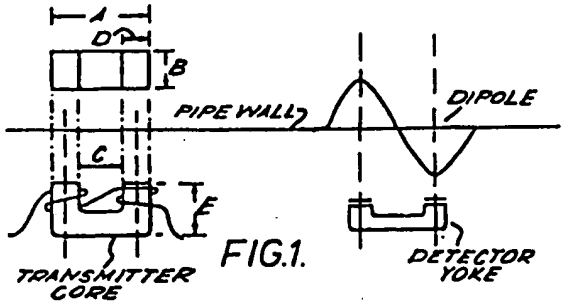

FIG.1.

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The invention relates to instrumentation for measuring velocity and/or distances and in particular relates to instrumentation for measuring the velocity or distance or both of an inspection vehicle travelling inside a ferromagnetic pipeline.

It is known to use mechanical devices to measure distances or velocities. Such mechanical devices work by reason of contact between the vehicle and the static surface over which it is moving usually by means of a wheel. However, mechanical devices suffer for inaccuracies owing to slippage or skidding of the entacting surface or to bouncing off the surface.

The present invention seeks to provide a system for measuring velocities and distances wherein the measuring apparatus does not physically contact the surface over which it is travelling.

In accordance with the present invention there is provided a measuring system comprising

(i) a transmitter for implenting a magnetic dipole on a ferromagnetic surface

(ii) means remote for said transmitter for detecting said implanted magnetic dipole

(iii) means for triggering said transmitter, said triggering means being responsive on output signal for said detecting means upon detecting an implanted magnetic dipolse, and

(iv) means for measuring and representing the line elapsed between the time the dipole is implanted and subsequently detected.

The invention will be described in greater detail by reference to the following example and the accompanying drawings.

The basic system consists of a 'u' shaped transmission core wound with, for example, enamelled wire. Current pulses are fed to the transmission coil, for example, from a fifteen volt transistor pulsing circuit, the peak value of each pulse being dependent on the gap between the limb faces and the pipe surface for any fixed coil arrangement.

The detector is preferably the form of a full bridge with each arm containing a magneto diode. Each pair of diodes is attached to the limbs of a 'u' shaped metal yoke, the yoke's purpose being to complete the magnetic circuit in the vicinity of the pipe wall, the spatial separation of the diodes correlating with the geometry of the imprinted dipole, Fig 1.

The detector signals are processed in real time; signals from the bridge are band limited then subtracted. The resulting signal, after amplification, being used to calculate velocity, indicate distance and request a further pulse.

In a preferred form of the invention the detector is formed by four magneto diodes in a bridge configuration cemented to a 'u' shaped steel former with dimensions as outlined in Fig 2. The power supply to the detector is taken from a simple regulator circuit maintaining approximately six volts across the diode pairs, Fig 3.

It has been found that output signal variations were due more to the changing characteristics of magneto-diodes than to changes in yoke materials, but did show a dependence on detector width. The optimum width obviously depends on transmission core dimensions, but the trend showed an improvement in signal strength with widths up to approximately 200% of the transmission core width; with widths much larger than this signal strength deteriorates.

The two detector signals are not identical. One signal tends to a monopolar form while the second is bipolar in nature. The signals are however, predictable and consistent. The reason for this dissimilarity has been attributed to interactive flux within the metal yoke.

The transmission cores may be 400 Hz (0.004 inches laminate thickness) 'C' cores wound with 36 or 34 swg enamelled wire.

An evaluation of transmission cores with various amp-turn values is shown in graph form, Fig 4. The detector, detector height and plate position held constant throughout the tests. One, one millisecond pulse applied to the coil produces a peak current with a value dependent on wire resistance, distance from plate and system time constants. A circular metal plate fixed on a rotary rig has a magnetic

dipole induced into a localised region on its surface by the transmission coil, whose height above the plate can be altered.

The moment the transmission coil is pulsed flux builds up in the metal core. When the core is in contact with the metal plate the majority of the flux passes through the plate, the result being the imprinting of a dipole. As the transmission core is lifted off the metal plate there is an available path for lines of flux across the leakage gap between the poles of the transmission core. The higher the lift off the greater the total reluctance in the magnetic circuit, the greater the tendancy for flux to leak across the gap, so the weaker the imprinted dipole. Once the pulse has been applied the plate is set in motion and the induced dipole detected by the detector. The signal from the two pairs of diodes on the detector are displayed on a UV record and an arbitiary value for signal strength determined from the average peak to peak values of the two signals over five repetition cycles (The dipole remains in the plate with the same strength for an unlimited period).

With a lift off height of up to approximately $\frac{1}{8}$" from the plate surface the impedance of the coil changes, the result being an increase in current with lift off up to the final saturation peak current which remains constant over $\frac{1}{8}$" lift off.

As can be seen from Fig 4 the characteristic shape for lift off against signal strength is a high peak (off the graph) at zero lift off followed by a well leading to a secondary hump at approximately $\frac{1}{8}$" lift off. Signal strengths are not indicated for values below

1/16" lift off due to the difficulties in maintaining the required gap size.

The build up of current in the coil is exponential. If, however, a square current waveform is assumed, then the average power is given by:

$$\frac{VI\ ton}{} \qquad (1)$$

where V = system voltage
I = coil current
ton = time pulse applied
= repetition period

The period, with a distance of 1 foot between transmitter and detector and at a velocity of 15 ft/sec is:-

$$\frac{1}{15} = 66.67 \text{ ms}$$

The average power delivered by the source is given by (1)

Therefore $2.75 \times \frac{1}{66.67} = 0.607$ watts.

This value is obviously dependent on the period, which is governed by the velocity of the system and by the spacing between transmitter and detector.

It is not essential to inject energy into the pulsing system each time a dipole is detected. "N" detectors set at fixed distances from the transmitter can be used to divide the power consumed by N. If 'N'

takes the value of '2', the first detector detects the dipole and indicates this fact, the velocity or distance being determinable from the time taken or distance travelled between the transmitter and first detector. The dipole remains in the pipe wall and a further value for velocity or distance is determined from the time taken or distance travelled between the first detector and the second. The system repulses on acknowledgement from the second detector that a dipole has been recognised. It does not matter to the nth detector whether the n - 1 th component is a transmitter imprinting a new dipole previously imprinted. It has the advantage of reduced power consumption but the error reduction system will need to be more complex.

Using as a standard transmission core the 1st 'C' core with dimensions as indicated in Table 1, the frequency bandwidth for 0.5 to 15 ft/sec is approx 10 to 400 Hz. These frequencies reduce the larger the core length.

TABLE 1

DIMENSIONS IN INCHES

Core *	A	B	C	D	E
1st	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$
2nd	$1\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	1
2nd Stripped	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{4}$
3rd	$1\frac{9}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{9}{16}$

* See Figure 1 for spatial arrangements of parameters A - E

The detector will transmit to the processing electronics a function containing the required signal plus noise. The noise can be assumed random and containing all frequencies to the upper frequency limit of the diode detectors. The signal component is predictable in character and lies within preset frequency limits determined by core limb spacing and vehicle speed. To enhance signal to noise ratio the redundant signal levels, ie high and low frequency noise can be eliminated by direct filtering. Both channels from the detector head are band limited in this way and fed into the electronic side of the spacial correlator, Fig 5. As the detector yoke passes over the imprinted dipole a signal is transmitted by each limb, the difference in the two signals being their phase relationship, Fig 6. The correlation section subtracts the two channel signals, removing a large proportion of synchronous noise and increasing the signal strength by the sum of the opposite peak values, the result being further increase in signal to noise ratio.

It is important for the detector system to be able to distinguish between a dipole and other magnetic disturbances in the area. The methods used so far to try and ensure a minimum error detection rate are spatial correlation and band limiting. Spatial correlation is the result of the diode separation on the detector yoke matching the spacial geometry of the imprinted dipole. Only in a matched condition will a peak signal level result. It is believed therefore, that small magnetised defects will pass through undetected unless their magnetisation strength is much higher than that of the dipole. If the two signals from the detector bridge are monitored at the moment of

match, one will have a positive peak value and the other a peak negative. Use could therefore, be made of the 'AND' function to improve on noise immunity. The positive/negative condition should only prevail for signal dipoles unless an error defect matches the dipole configuration.

It has been observed that phenomena such as welds, flanges, etc, produced an output much greater than signal amplitudes. It is very easy to compensate for these abnormal signal strengths by windowing the signal input from the detector head and only allowing signals within set amplitude levels to be considered as control characters.

The time domain characteristics of the system are also predictable and can be used in an error minimisation system. It is possible that the system at some time will not detect an imprinted dipole. In the event of this happening, an error is introduced in the velocity/distance measurement. This error can be reduced to a minimum by:

(a) monitoring the velocity of the system and using this to control an automatic repulse unit. This unit will imprint a new dipole after a set time, the time limit set according to velocity. This unit has been termed a 'flywheel' system.

(b) In the same way as using a maximum time control variable in which to reprint, a minimum time control variable can be used to ensure that premature noise signals are not mistaken as control characters. A basic system for windowing and

setting minimum and maximum time variables is outlined in Fig 7.

A number of pull through tests were carried out using on board power supplies delivering 2.75 amps at 15 volts. The free running pulse system fed the 'lst' transmission core wound with 200 turns of 36 swg enamelled wire (Table 1), dipoles being detected with the third detector head, Fig 2. The shoes were positioned approximately 1½ feet apart. The detector and transmission cores potted in brass shoes with 'ferrobestos' face material. This is non-conducting and, therefore, limits the possibilities of pulse distortion due to eddy currents. Care should be taken to ensure accurate alignment of transmitter and detector when mounted on the carrier vehicle since mis-alignment by ±100% of the transmitter core limb width would seriously degrade the detected signal. Output signals are transmitted along co-axial cables into an amplification panel and subsequently recorded on both UV and magnetic tape. It is obvious from recorded tests that flanges and welds can be easily detected and using a suitable amplitude window function can be eliminated. It is a necessity for the same reason to limit the gain of the output signal. Initially the signal was amplified into saturation and it proved very difficult to differentiate flanges and welds from signals at certain points.

Short regions of reduced signal strength or loss of signal have been attributed to twisting of the vehicle in the pipe due to torsional force exerted by the umbilical cable. The vehicle did change orientation during its passage down the line. A simple weight fixed

and hung at right angles to a potentiometer spindle can be used to monitor changes. A proportion of the voltage applied across the potentiometer is tapped by the slide according to angular position of the potentiometer spindle. The shoe path can then be determined quite accurately.

No signal can be recorded over voltage saturation areas such as welds or flanges, but if a signal is required to pass over a weld or flange it should be possible to either straddle the area with two systems or to use the saturation of a weld or flange as a starting point marker for each length. The methods used are totally dependent on the resolution and accuracy required.

The pulsing system as used on pull through tests is shown in Fig 8.

The NE566T is a function generator capable of producing a square wave output on pin 3, the frequency of which is dependent on the values of R_3C_2. This signal is differentiated and fed to pin 4 of the 74121 monostable producing a fixed duration pulse on pin 6, the duration being set by R_7. The pulse is fed to the base of Q_2 turning it on, lowering its collector voltage to Vce (sat). This sends the Darlington transistor Q_3 into saturation raising its collector voltage to 15 - Q_3 Vce (sat) volts enabling a current pulse approximately 1 ms duration to pass through the transmission coil L. The diode D, is included to limit overshoot in the current waveform and C_5 to reduce the time constant of the transmission waveform.

The time domain characteristics of the velocity/distance measurement system are well defined for specific velocity limits. It should, therefore, be possible to limit error triggering with a preset or variable timing system.

A signal from the pulsing unit initiates a timing cycle for T_2 and T_3 which can be set according to a control signal from the velocity circuit. These govern the period over which an input signal from the correlation circuit can be used as a control character. If T_3 is the end limit timing shutter then at the end of its timing cycle a request for a repulse will automatically be given.

Level 1 and 2 form the amplitude limits of the window function, where the function is zero for all values of input signal outside the window limits.

The yoke signal is buffered by Q_1, Fig 9, and fed to the high pass filter stage C_1, R_3 giving a transfer function

$$\frac{SC_1R_3}{R_3SC_1+}$$

with a 3dB asymptote at:

$$\frac{1}{R_3C_1} = Wc_1$$

The signal is amplified by A_1 with a gain of $\frac{-R_5}{R3}$, this feeds a low pass network formed by R_7, C_3. C_3 being effectively shunted by R_9, the input impedance of the correlation unit. It should be noted that the second

channel sees an effective shunt impedance of twice the resistance, R_9, hence the capacitance value of C_4 must be half the value of C_3 to maintain symmetry in the processing system.

The response of the low pass network is:-

$$\frac{R_9}{R_7+R_9}\left\{\frac{1}{\frac{R_7R_9SC_3}{R_7+R_9}+1}\right\}$$

with a 3dB asymptote

$$\frac{R_7+R_9}{R_7R_9C_3}=\omega_{c2}.$$

The correlation section consists of A_3, R_9, R_{12}, R_{10}, R_{11}.

$$V_{out}=-V_1\cdot\left\{\frac{R_{12}}{R_9}\right\}+V_2\cdot\left\{\frac{R_{10}}{R_{10}+R_{11}}\right\}\cdot\left\{\frac{R_9+R_{12}}{R_9}\right\}$$

If $R_{12}=R_9=R_{10}=R_{11}$

$$V_{out}=V_2-V_1$$

Channels A and B are buffered before connecting to the line drivers. The correlation unit subtracts the out of phase signals to produce the correlation signal.

Extra filtering was added to the two detector yoke output signals to limit noise and assist in driving the recording units.

Fig 10 shows the complete two channel unit. The input impedance of transisto Q_1, in the emitter follower mode is given by:-

$$Z_{in}=\frac{R_5R_6}{R_5+R_6}\Big/\!\Big/\left[h_{ie}+R_e(1+h_{fe})\right]$$

and since

$$R_e(1+h_{fe})\gg h_{ie}\gg\frac{R_5R_6}{R_5+R_6}$$

The filter network is effectively shunted by $\frac{R_5R_6}{R_5+R_6}$

The network resistor R_6 will in effect be $R_6//R_5$, but for case of notation wi be called only h_6'.

The network transfer function is given by:

$$V_{in} = \frac{R_1 V_{out}}{R_6'} + \frac{R_1}{R_3}\left(V_{out}\left(1+\frac{1}{R_6' S C_3}\right)\left(S R_3 C_1 + 1\right) + V_{out}\left(1+\frac{1}{R_1' S C_3}\right)\right.$$

with

$$\frac{V_{out}}{V_{in}} = \frac{S R_1' R_3 C_3}{R_1\left(R_6' S C_3 + 1\right)\left(R_3 S C_1 + 1\right) + R_6' S C_3 + R_1 S C_3 + 1}$$

$$= \frac{S R_6' R_3 C_3}{S^2 R_1 R_6' R_3 C_3 C_1 + S\left(R_1 R_6' C_3 + R_1 R_3 C_1 + R_6' C_3 + R_1 C_3\right) + \left(R_1 + 1\right)}$$

which is band pass in form with poles at:-

$$\frac{-\left(R_1 R_6' C_3 + R_1 R_3 C_1 + R_6' R_1 + R_1 C_3\right) \pm \sqrt{\left(R_1 R_6' C_3 + R_1 R_3 C_1 + R_6' R_3 + R_1 C_3\right)^2 - \frac{\left(R_1 + 1\right)}{R_1 R_6' R_3 C_3}}}{2 R_1 R_6' R_3 C_3 C_1}$$

CLAIMS

1) Apparatus for measuring velocity and/or distance which is mounted on a vehicle said apparatus comprising:-

i) a transmitter for implanting a magnetic dipole on a ferromatic surface.

ii) a detector located on the vehicle at a point remote from the transmitter for detecting an implanted magnetic dipole.

iii) means for triggering said transmitter, said means being responsive to an output signal from said detector upon detecting an implanted magnetic dipole and

iv) means for measuring and representing an output signal from said detector, said signal being a function of the time elapsed between implantation of the dipole and detection of the same.

2) Apparatus as claimed in Claim 1 wherein separate detectors are used to generate output signals for the triggering means and for measurement and representation of the time function.

3) Apparatus as claimed in Claim 1 and Claim 2 wherein the detector comprises a metal yoke having two magneto diodes attached to the free of each limb, said magneto diodes being electrically connected to form bridge configuration.

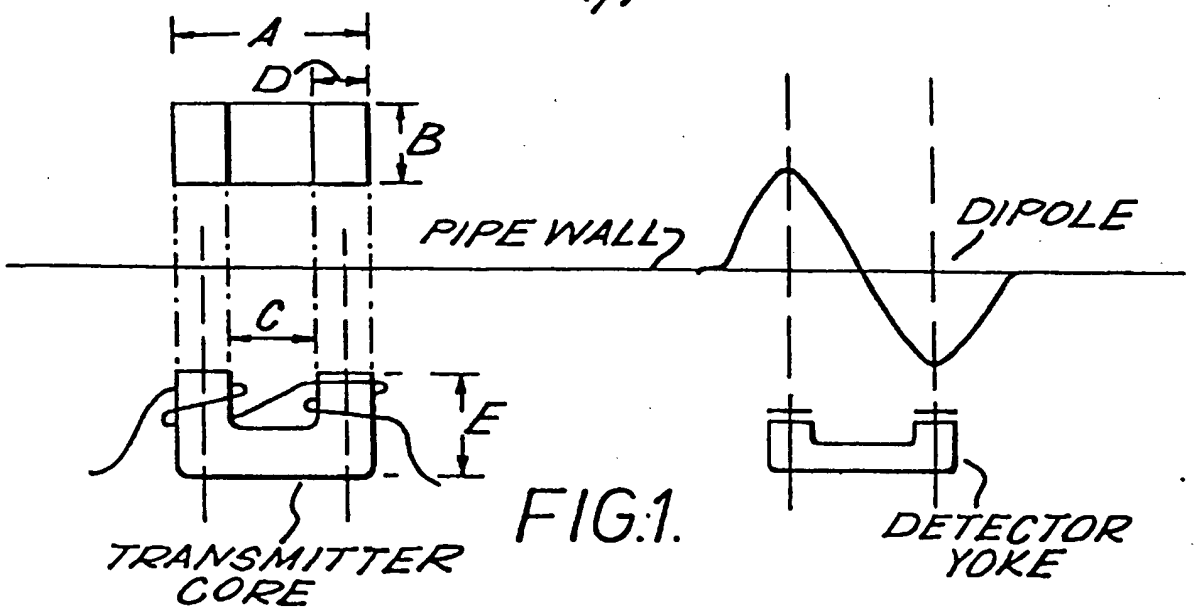


FIG.1.

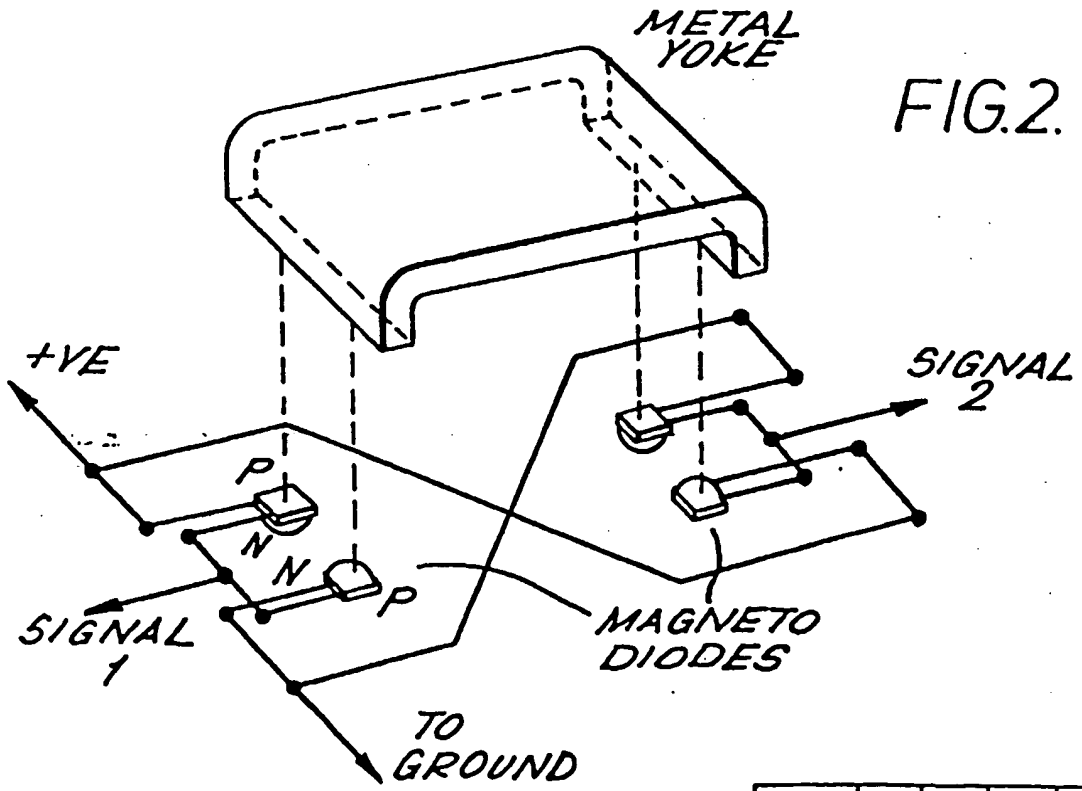
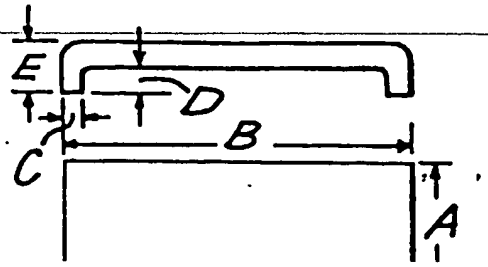


FIG.2.



YOKE	A	B	C	D	E
SMALL	10	10	4	2	7
2ND	12	25	3	3	6
3RD	12	21	3	3	6
SPLIT	14	33	3	3	6

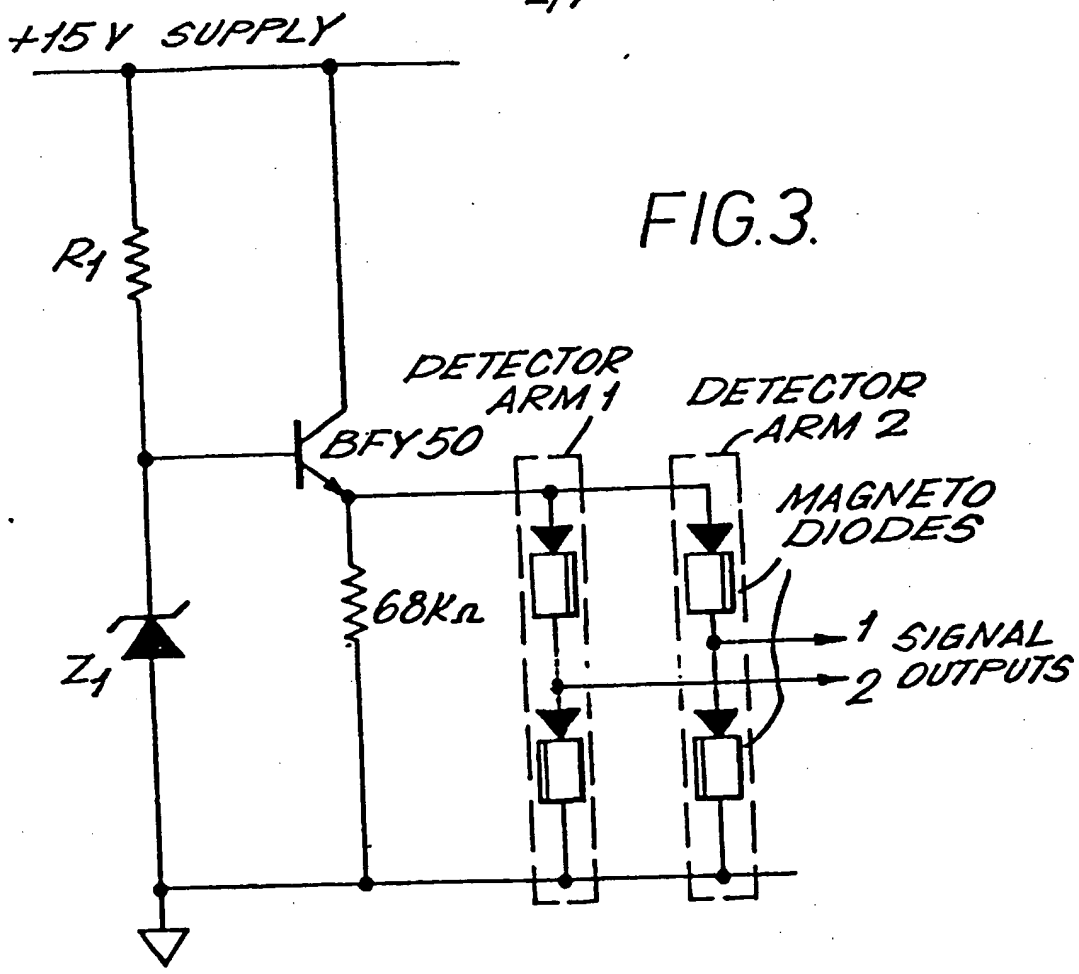

+15 V SUPPLY
R1
Z1
BFY50
68Kn
DETECTOR ARM 1
DETECTOR ARM 2
MAGNETO DIODES
1 SIGNAL OUTPUTS
2

FIG.3.

FIG.4a.

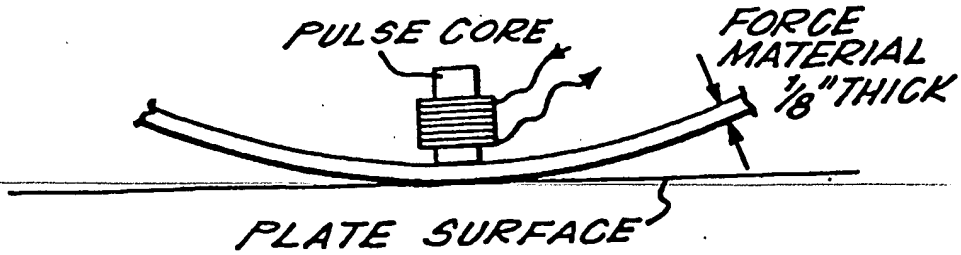
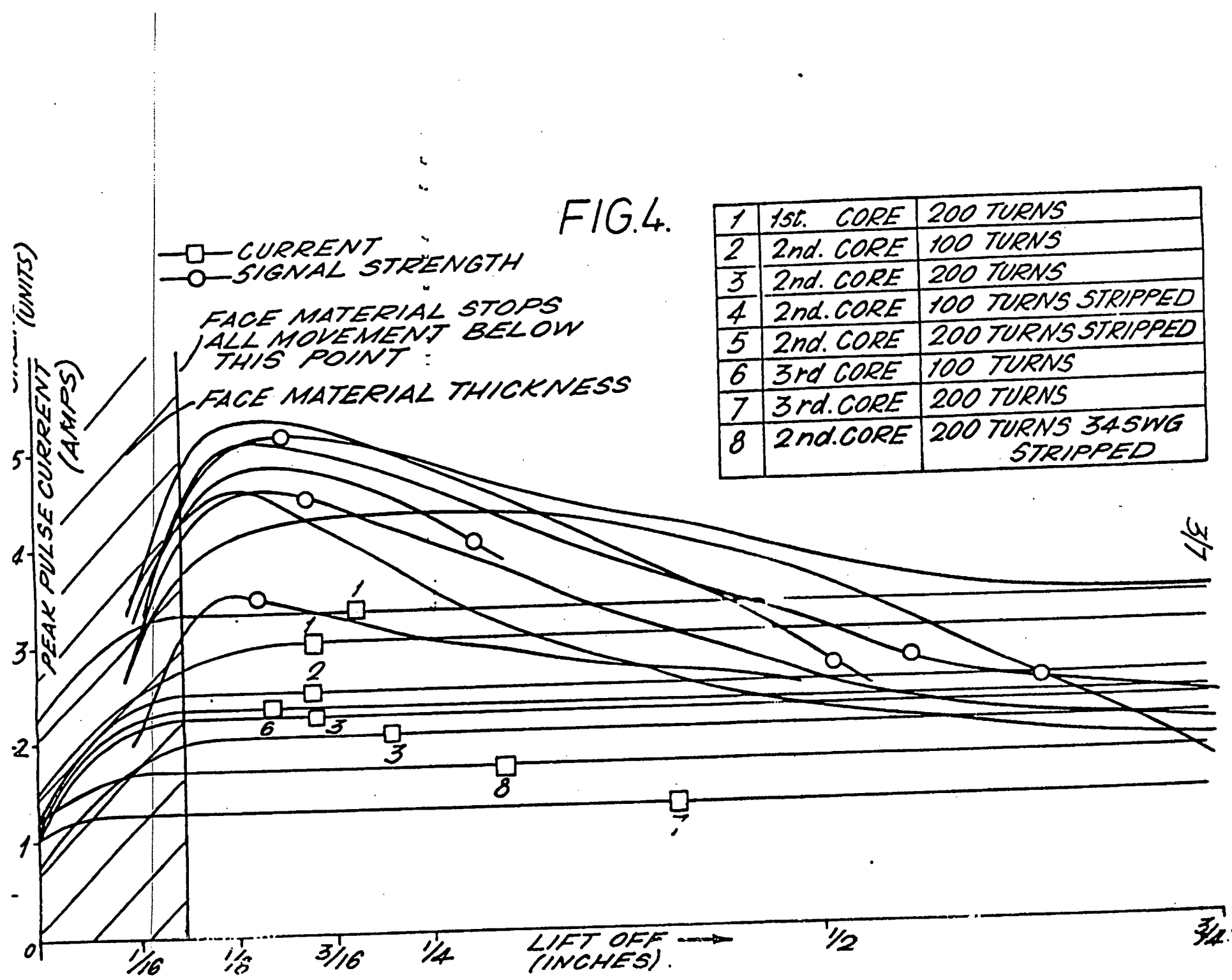

PULSE CORE
FORCE MATERIAL
1/8" THICK
PLATE SURFACE

FIG.4.

1	1st. CORE	200 TURNS
2	2nd. CORE	100 TURNS
3	2nd. CORE	200 TURNS
4	2nd. CORE	100 TURNS STRIPPED
5	2nd. CORE	200 TURNS STRIPPED
6	3rd CORE	100 TURNS
7	3rd. CORE	200 TURNS
8	2nd. CORE	200 TURNS 34SWG STRIPPED



00013494

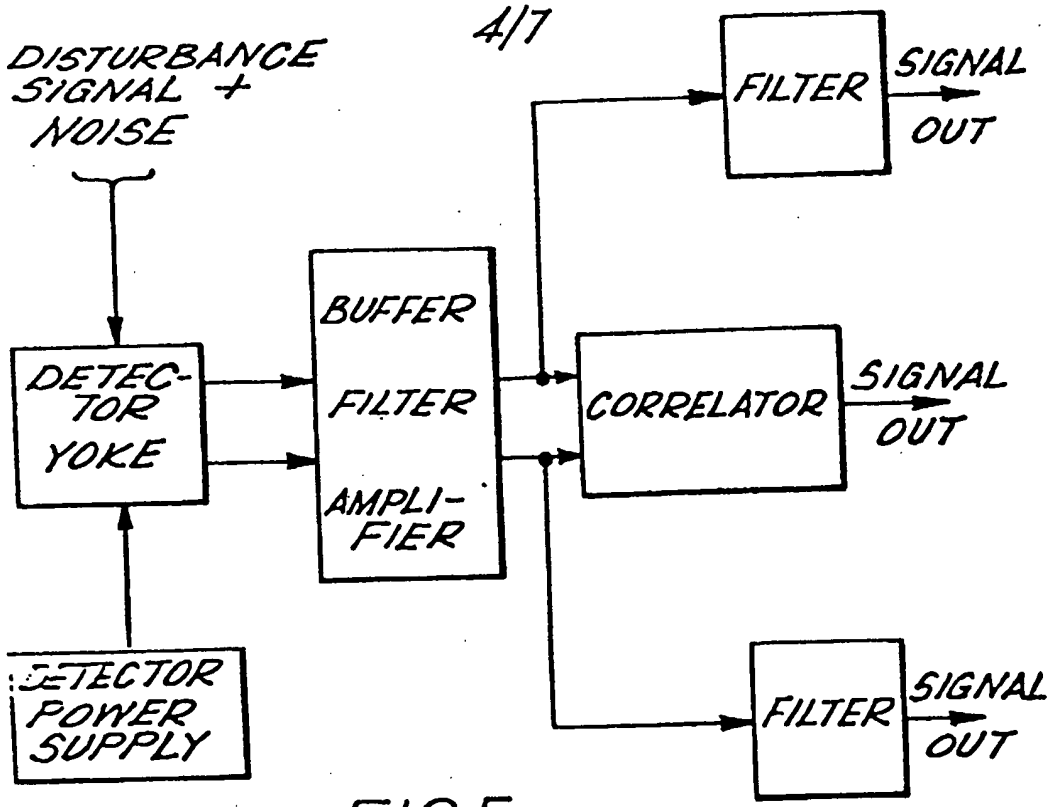

DISTURBANCE SIGNAL + NOISE
DETEC-TOR YOKE
BUFFER
FILTER
AMPLI-FIER
FILTER
SIGNAL OUT
CORRELATOR
SIGNAL OUT
DETECTOR POWER SUPPLY
FILTER
SIGNAL OUT

FIG.5.

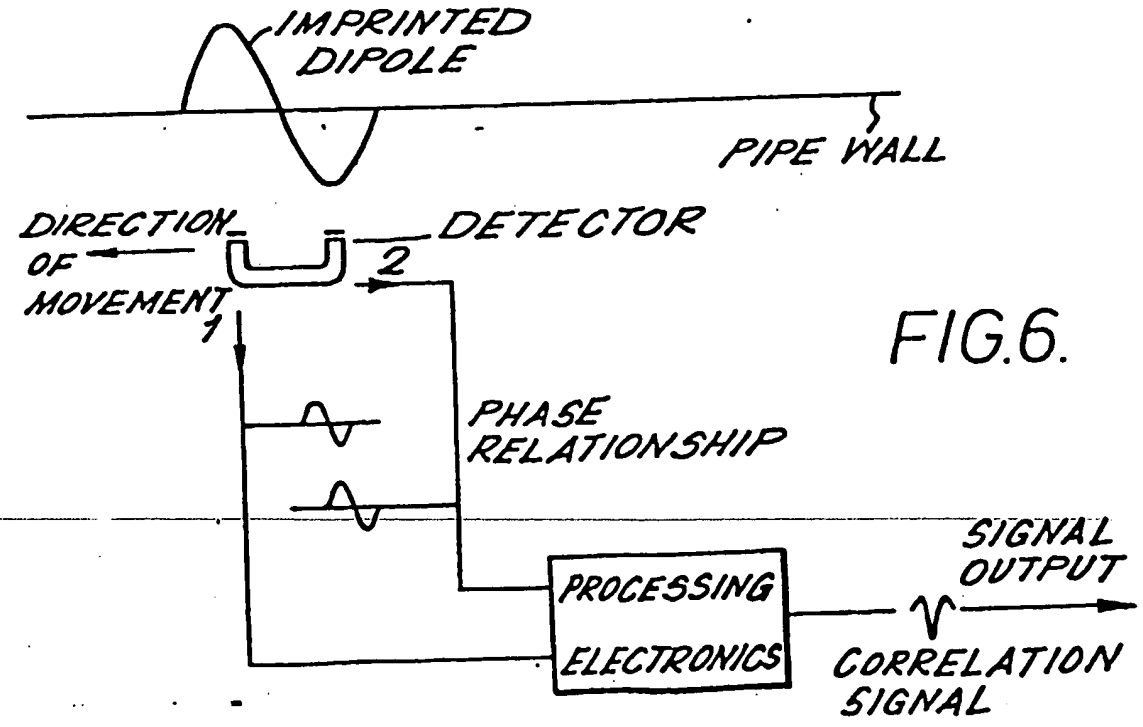

IMPRINTED DIPOLE
PIPE WALL
DIRECTION OF MOVEMENT
DETECTOR
2
1
PHASE RELATIONSHIP
PROCESSING ELECTRONICS
SIGNAL OUTPUT
CORRELATION SIGNAL

FIG.6.

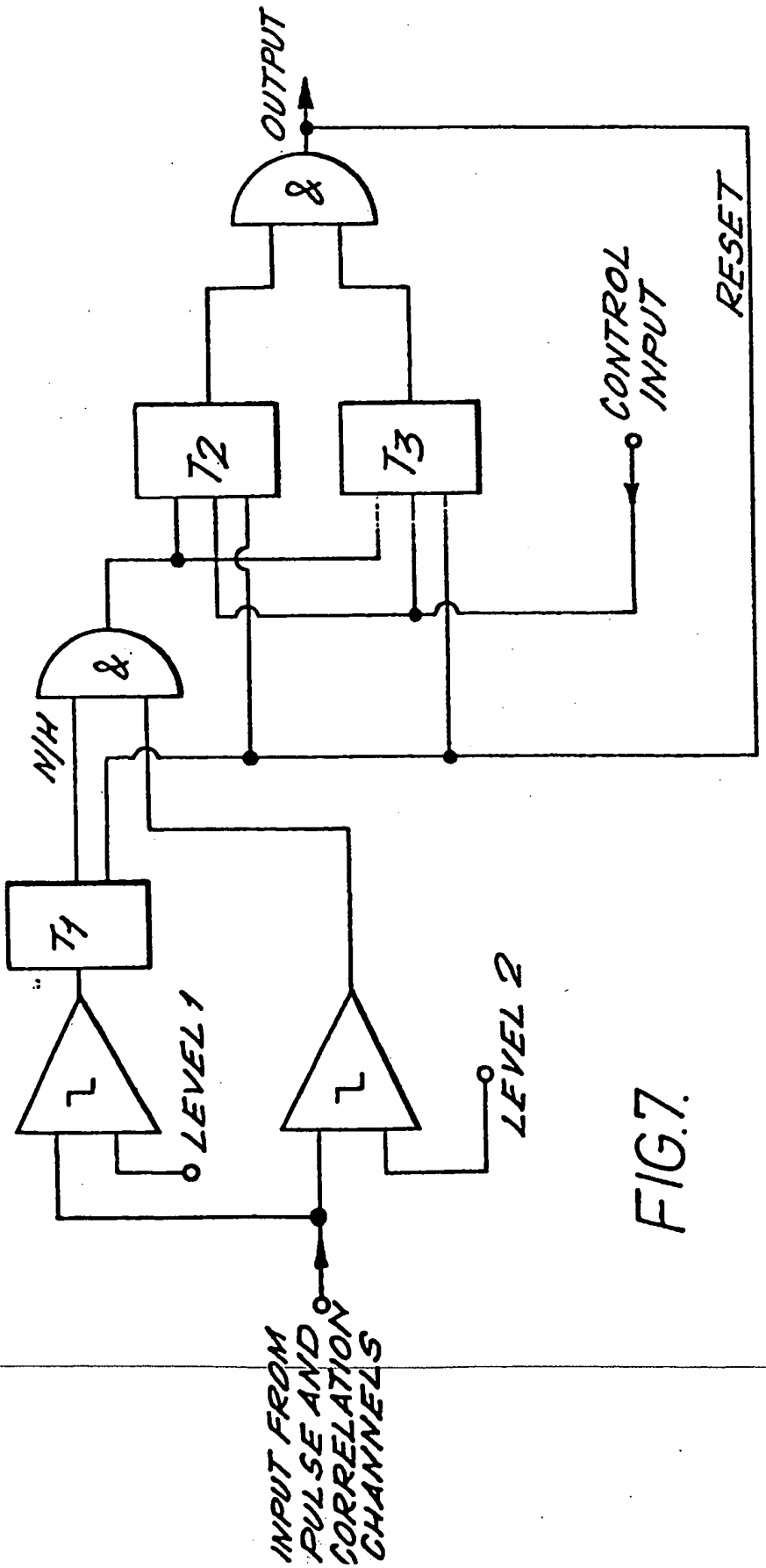

OUTPUT
&
RESET
CONTROL INPUT
T2
T3
&
N/H
T1
LEVEL 1
LEVEL 2
INPUT FROM PULSE AND CORRELATION CHANNELS

FIG.7.

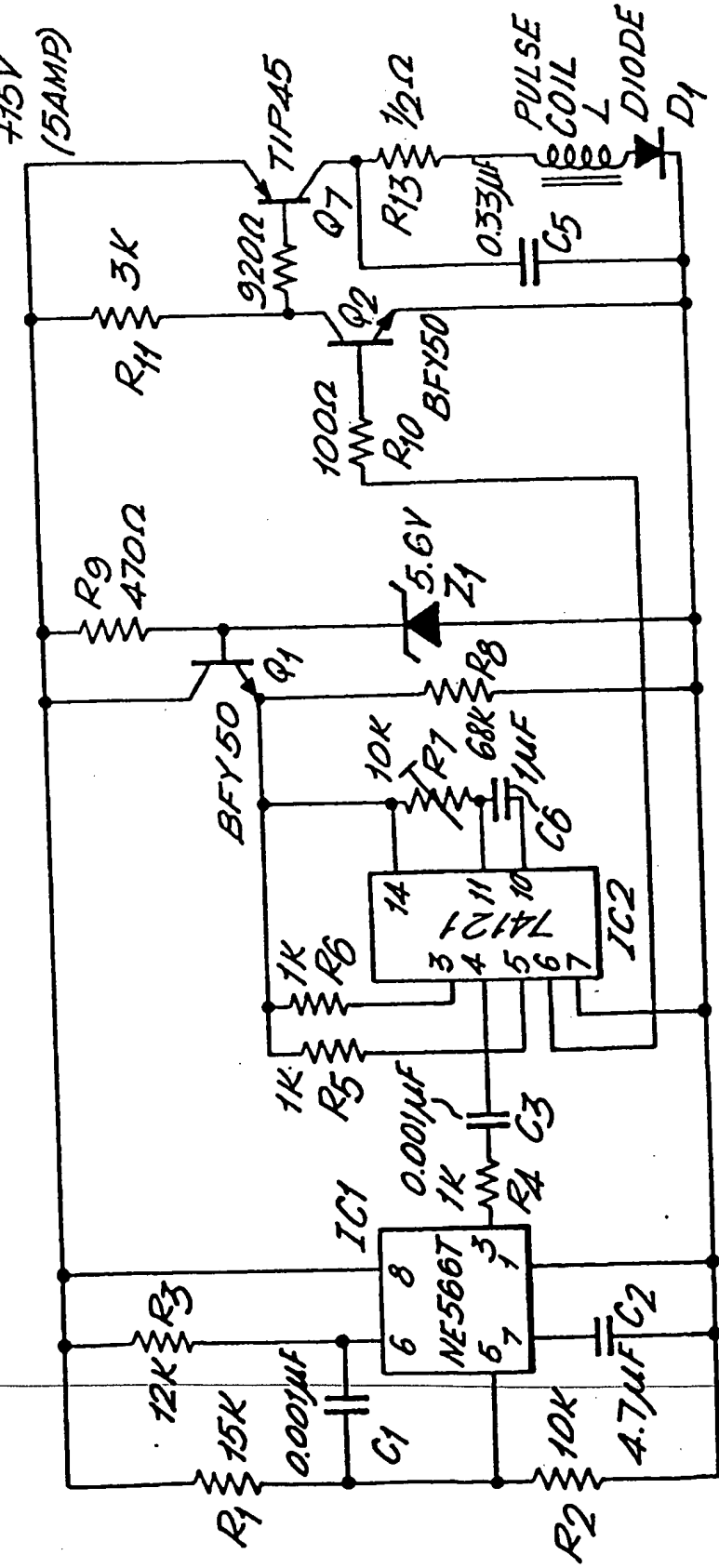

+15V
(5AMP)
TIP45
Q7
R13
½Ω
PULSE
COIL
L
DIODE
D1
0.33μF
C5
3K
R11
920Ω
Q2
BFY50
100Ω
R10
R9
470Ω
5.6V
Z1
Q1
R8
BFY50
10K
R7
68K
1μF
C6
IC2
7412
1K
R6
1K
R5
0.001μF
C3
IC1
0.001μF
1K
R4
NE5667
R3
12K
15K
0.001μF
C1
4.7μF
C2
10K
R1
R2

FIG.8.

FIG.9.

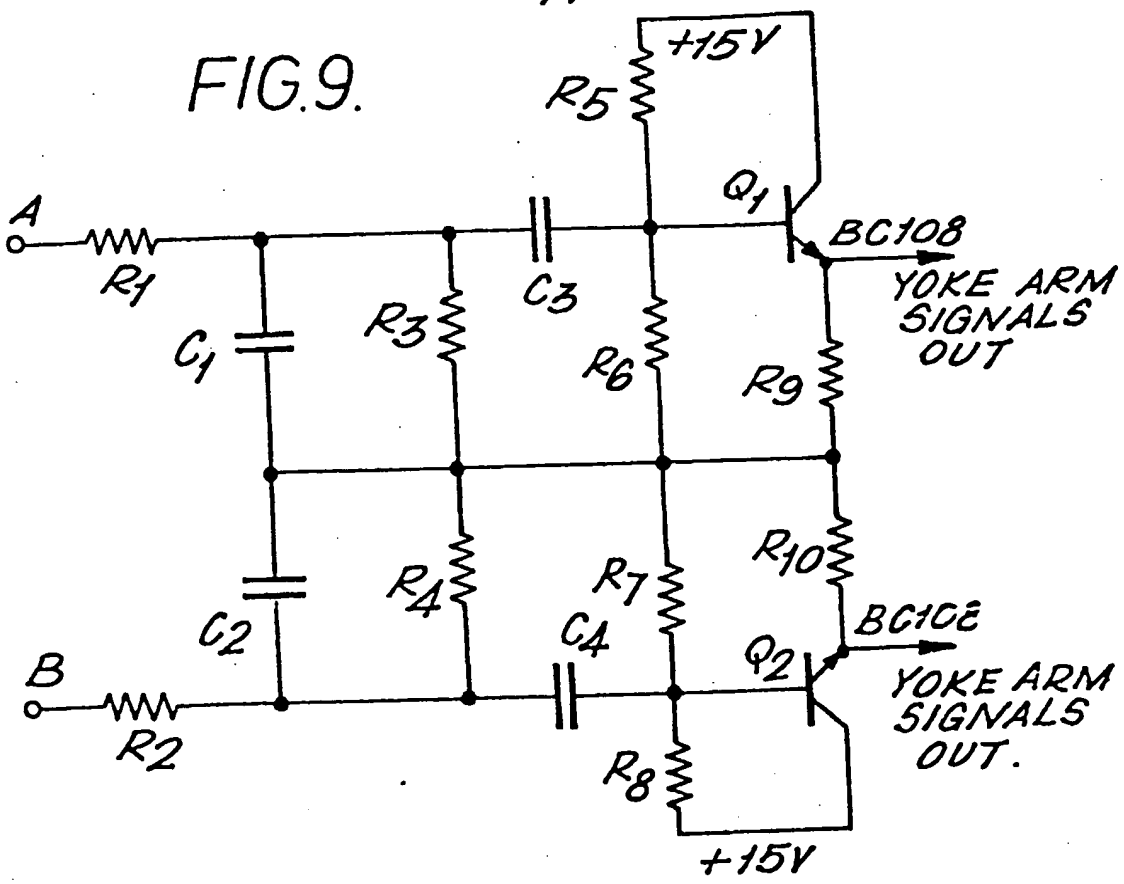
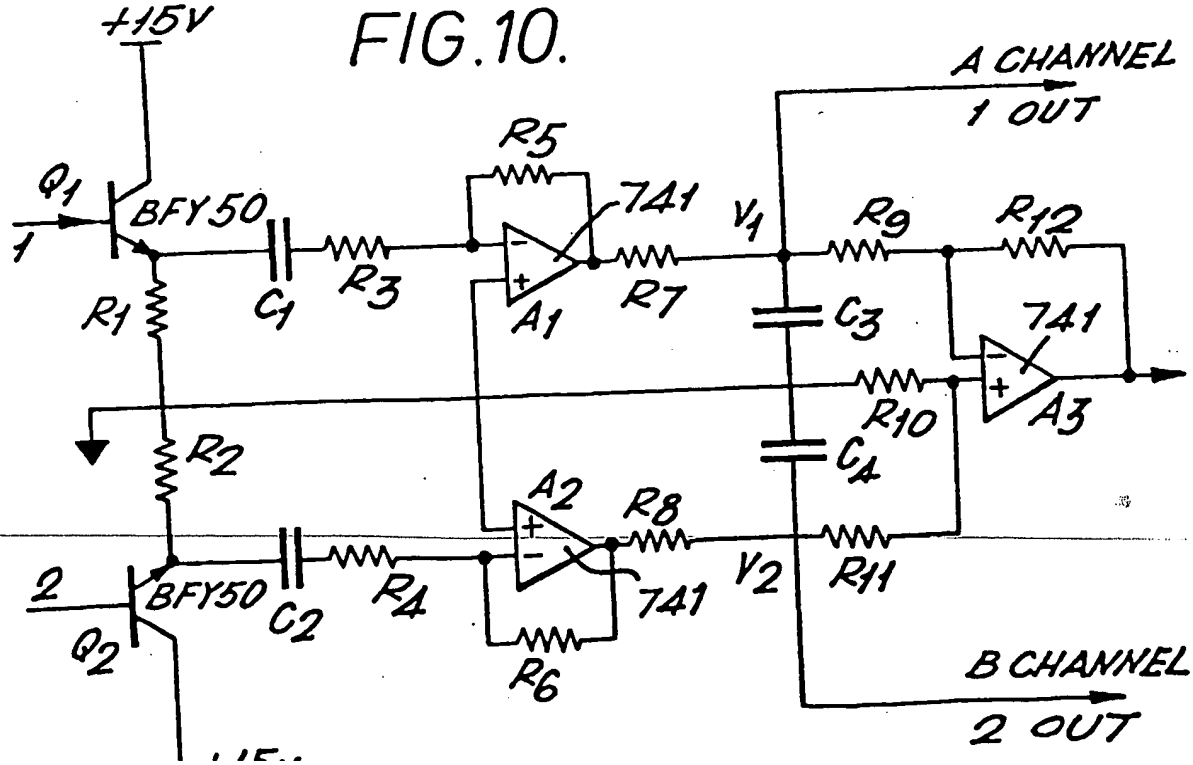

+15V
R5
Q1
BC108
A
R1
C3
YOKE ARM SIGNALS OUT
C1
R3
R6
R9
R10
R7
R4
C2
C4
BC108
Q2
B
R2
YOKE ARM SIGNALS OUT.
R8
+15V

FIG.10.


+15V
A CHANNEL 1 OUT
R5
Q1
BFY50
741
V1
R9
R12
1
R3
C1
R7
A1
R1
C3
741
R10
A3
R2
C4
A2
R8
2
BFY50
C2
R4
741
V2
R11
Q2
R6
B CHANNEL 2 OUT

European Patent Office

EUROPEAN SEARCH REPORT

0013494
Application number

EP 79 30 2872

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int Cl.)
Category	Citation of document with indication where appropriate, of relevant passages	Relevant to claim	
	FR - A - 2 203 148 (NIPPON KOKAN KABUSHIKI KAISHA) * Page 9, line 27 - page 10, line 34; page 13, lines 16-21; figures 3,7 *	1,2	G 01 P 3/66 G 01 B 7/04 21/06
	FR - A - 1 549 170 (DELLE-ALSTHOM) * Page 2, column 1, lines 41-43; page 2, column 2, lines 7-16; page 3, column 1, lines 8-15, 29-48; figures 6-9 *	1,3	
	GB - A - 1 173 379 (LOGIC SYSTEMS, INC.) * Page 3, line 122 - page 4, line 18; figures 3,7 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.) G 01 P 3/50 3/54 3/64 3/66 G 01 B 7/04 21/06 E 21 B 47/09
A	US - A - 3 862 497 (B. VERNOOY et al.) * Column 3, lines 3-16; figure 1 *	1	

CATEGORY OF CITED DOCUMENTS

- X. particularly relevant
- A technological background
- O: non-written disclosure
- P intermediate document
- T theory or principle underlying the invention
- E: conflicting application
- D: document cited in the application
- L citation for other reasons

& member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14-03-1980	HANSEN

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